TITLE: FUNDAMENTAL STUDY OF LOW-NOX COMBUSTION FLY ASH UTILIZATION

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ABSTRACT

OBJECTIVE

This project is a collaborative effort between two universities (Brown and Princeton) and an electric utility (formerly New England Power, now US Generating Company). The goal is to provide a more basic understanding of the nature of the organic fraction of the fly ash and its role in various utilization schemes. Four specific tasks have been defined:

1. Characterization of the physical and chemical nature of ash organics. This task involves a) acquiring a suite of fly ash samples from utilities throughout the country, b) characterizing this set of samples with respect to organics (carbon and extractables) content, surface area and chemistry and pore structure.
2. Development of new screening tests to evaluate the suitability of the ash with respect to various possible "beneficial use" applications.
3. Characterization of the adsorption behavior of selected fly ashes relative to various organic and inorganic adsorbates.
4. Examination of the technical suitability of high carbon fly ash as a low-cost alternative to activated carbons in adsorption applications.

ACCOMPLISHMENTS TO DATE

A sample bank containing over 75 fly ash samples has been assembled. This bank contains ashes that are mainly typical of utility practice with a few that are atypical of common practice, but providing special insight into the nature of the organic fraction. The bank contains both class C and class F ashes, obtained from a variety of boiler types and firing configurations (tangential, wall-fired, cyclone, fluidized bed, low-NOx) and from coals of various rank. There are also samples obtained from unique co-firing situations and

from combustion of pulverized oil shale. All of the sample have been subjected to characterization with respect to LOI (a measure of organic or unburned carbon content), surface area and porosity (of both the mineral and carbon components), the reactivity of the residual carbon towards oxygen, and the propensity of the carbon to participate in the adsorption of air entraining agents (specialty surfactants added to concrete in order to impart freeze-thaw resistance to the concrete). In addition, selected samples have been tested for extractable organics content and for the polarity of their surfaces. Other selected samples have been tested with respect to their propensity to adsorb ammonia. This is of increasing interest in the context of increasingly stringent NOx emissions standards which would require installation of SCR or SNCR technologies. The issue of ammonia retention on ash looms as a large potential problem in such a scenario.

Based upon the above testing, we have concluded that the carbon in fly ash plays the major role in adsorption of air entraining agents. It also plays the key role in adsorption of ammonia from the dry, pure state. The mineral components of fly ash contribute little to both of these phenomena. In both cases, the surface area that the unburned carbon presents is a key factor determining the capacity for uptake. In this respect, the carbon behaves much as would any other activated carbon. In addition to internal surface area, the accessibility of the carbon and the polar nature of its surface both play key roles in determining its adsorption capacity. This understanding has indicated possible practical approaches for handling "problem" ashes, and these are being explored outside of this project, in partnership with EPRI and industry.

SIGNIFICANCE TO FOSSIL ENERGY PROGRAMS

The Nation faces a serious question concerning what to do with fly ash from coal fired power stations. Only about 1/6 of this ash is presently utilized in cement and concrete products, and this is by far the largest single reuse market. Most of the remainder is landfilled. Only a few days ago did EPA decide to renew the RCRA hazardous waste exemption that coal fly ash has enjoyed, but promised to continue to revisit the issue. Reclassification of the ash as hazardous waste would have a huge negative impact on the Nation's coal-based utilities, just at a time when they are adjusting to the new deregulated power environment. The economic driving force for increasing beneficial use alternatives to landfilling will probably continue to grow, as such beneficial use would be exempt from hazardous waste penalties. This project offers very practical insights into what features of the carbon in ash limit, or promote, the beneficial use possibilities. Based upon the results already obtained, new contacts have been developed with other utilities, the Electric Power Research Institute, and with ash marketers. These contacts will result in development of practical new technologies for overcoming some of the key barriers to greater utilization of this major fossil fuel co-product.

PLANS FOR THE UPCOMING YEAR

The project is now in its final phases. There are a great many new data in hand, and attention has turned to analyzing these further. There will be continued attention given to the problem of defining a more quantitatively reliable alternative to the "foam index" test for air entraining agent sorption. Also, the burnout characteristics of the carbon in fly ash will be further examined.

ARTICLES AND PRESENTATIONS, AND STUDENTS RECEIVING SUPPORT

Journal Articles (peer reviewed)

• L. Hachmann, A. Burnett, Y.M. Gao, R.H. Hurt and E.M. Suuberg, "Surfactant Adsorptivity of Solid Products from Pulverized-Coal Combustion under Controlled Conditions" 27th Symposium (Int.) on Comb.,The Combustion Institute, Pittsburgh, pp.2965-2971, 1998.

• E. Freeman, Y.-M. Gao, R.H. Hurt and E.M. Suuberg, "Interaction of Carbon-Containing Fly Ash with Commercial Air-Entraining Admixtures for Concrete", Fuel, 76, 761-765 (1997).

• Y.-M. Gao, H.-S. Shim, R.H. Hurt, E.M. Suuberg and N.Y.C. Yang, "Effects of Carbon on Air Entrainment in Fly Ash Concrete: The Role of Soot and Carbon Black", Energy and Fuels, 11, 457-462 (1997).

Conference Presentations

• R.H. Hurt, E.M. Suuberg and Y.M. Gao " Fly Ash Research at Brown University", *EPRI Target Meeting on Coal Combustion Byproducts*, Long Beach, February, 2000.

• R.H. Hurt, E.M. Suuberg, Y.M. Gao and A. Mehta "The Passivation of Carbon for Improvement of Air Entrainment in Fly Ash Concrete", to be presented at the NETL *Conference on Unburned Carbon on Utility Fly Ash*, Pittsburgh, May, 2000.

• I. Külaots, Y.M. Gao, R.H. Hurt, and E.M. Suuberg "Characterization of Unburned Carbon in Coal Fly Ash and the Foam Index Problem", *Western Regional Ash Group Annual Meeting*, Denver, November, 1999.

• I. Külaots, Y.M. Gao, R.H. Hurt, and E.M. Suuberg "The Role of Polar Surface and Mesoporosity in Adsorption of Organics by Fly Ash Carbon", ACS Div. Fuel Chem. Preprints, 43, 980 (1998).

• K.A. Smith, I. Külaots, R.H. Hurt and E.M. Suuberg, "The Chemical Nature of Unburned Carbon Surfaces in Fly Ash - Implications for Utilization in Concrete", Proc. \1997 Int. Ash Utilization Symposium, pp. 650- 657, University of Kentucky, CAER, Lexington, KY, 1997.

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• N. Sabanegh, Y. Gao, E.M. Suuberg and R.H. Hurt, "Interaction of Coal Fly Ash with Concrete Surfactants: Diffusional Transport and Adsorption", Proc. 9th Int. Conf. on Coal Science, Vol.III, pp1907-1910, P&W Druck and Verlag, Essen, Germany, 1997.

• Y.M. Gao, H. Shim, R.H. Hurt, E.M. Suuberg, and N.Y.C. Yang, "Effects of Carbon Black and Fly Ash Carbon on Air Entrainment in Concrete", *12th International Symposium of the American Coal Ash Association*, Orlando, January, 1997.

• R.H. Hurt, E.M. Suuberg, Y.M. Gao, and P. Calvert, "Unburned Carbon in Ash: Formation, Properties, and the Behavior in Construction Applications", *EPRI Coal Quality Effects Conference*, Kansas City, 1997.

• R.H. Hurt, E.M. Suuberg, Y.M. Gao, N. Sabanegh, A. Burnett, "The Undesirable Adsorption of Concrete Surfactants on Porous Carbon in Coal Combustion Fly Ash", *Carbon '97*, Pennsylvania State University, July, 1997.

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